



# Review of ORAUT-RPRT-0099 Evaluation of Two Reactors for ORAUT-OTIB-0054 Applicability

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# Introduction

- ◆ This presentation to the Advisory Board on Radiation and Worker Health is based on the one given at the December 17, 2025, Idaho National Laboratory (INL)/Argonne National Laboratory-West (ANL-W) Work Group meeting as part of the assessment of the INL Special Exposure Cohort (SEC) Petition SEC-00219 and the ANL-W SEC-00256 evaluation reports (ERs).
- ◆ SC&A reviewed ORAUT-RPRT-0099 on the applicability of ORAUT-OTIB-0054 (“OTIB-0054”) to the Argonne National Laboratory’s Experimental Breeder Reactor-II (EBR-II) and Boiling Water Reactor Experiment-IV (BORAX-IV) reactors.
- ◆ SC&A concluded that the ORAUT-OTIB-0054 methodology and conclusions are valid for these reactors.

# Issue background

- ◆ SC&A identified a potential issue in its review of the two ERs:
  - Does ORAUT-OTIB-0054, “Fission and Activation Product Assignment for Internal Dose-Related Gross Beta and Gross Gamma Analyses,” adequately model the source terms of the site reactors and yield claimant-favorable dose results when actual mixtures of activation and fission products (MFAPs) are not available and only gross beta and gross gamma measurements are available?
- ◆ The National Institute for Occupational Safety and Health (NIOSH) asserts that the methodology and claimant-favorable assumptions of OTIB-0054 are expected to produce upper bound exposure results in most cases.
- ◆ Note: ANL-W is physically located within the overall INL site; the combined site is now referred to as “INL.”

# Reactor modeling history (1 of 2)

- ◆ SC&A made two evaluations in 2015 to determine whether ORAUT-OTIB-0054 produced acceptable results for six INL site reactors that operated during the SEC evaluation periods:
  - **Heat Transfer Reactor Experiments (HTRE)** (HTRE-1, HTRE-2, and HTRE-3 used in the Aircraft Nuclear Propulsion program, located in Test Area North): short fuel burnups, high temperatures, melted fuel, highly enriched uranium
  - **Materials Reactors** (Materials Testing Reactor (40 megawatts (MW)), Engineering Testing Reactor (175 MW), and Advanced Test Reactor (250 MW), located in the Test Reactor Area: high flux, light-water moderated, beryllium reflectors, highly enriched uranium curved fuel plates)
- ◆ The INL/ANL-W Work Group (WG) at its November 2015 meeting directed SC&A to create a prioritized list (with NIOSH's input) to examine OTIB-0054 applicability for the remaining reactors.

# Reactor modeling history (2 of 2)

- ◆ INL had 52 different reactors at various times: 34 at INL, 12 at ANL-W, 4 at Naval Research Facility (not in the program), and 2 never operated.
- ◆ SC&A considered all the applicable INL reactors not already analyzed and, in a 2016 report, “INL SEC-00219 Reactor Prioritization for Evaluation of ORAUT-OTIB-0054 Applicability,” placed them in “High,” “Medium,” and “Low” review categories considering the reactor designs and operating characteristics:
  - Fuel type, enrichment, cladding, moderator, reflector, coolant, operational mode, burnup
- ◆ NIOSH analyzed 2 (of 6) high-priority reactors, EBR-II and BORAX-IV, to assess if the ORAUT-OTIB-0054 methodology to assign radionuclide-specific intakes of MFAPs can determine internal doses adequately.

# NIOSH report and SC&A response

- ◆ NIOSH produced ORAUT-RPRT-0099, “Evaluation of EBR-II and BORAX-IV for ORAUT-0054 Applicability,” May 8, 2020.
- ◆ SC&A commented on ORAUT-RPRT-0099 in “Review of ORAUT-RPRT-0099, Evaluation of EBR-II and BORAX-IV for ORAUT-OTIB-0054 Applicability,” January 15, 2021.
- ◆ NIOSH and SC&A presented and discussed their reports at the December 17, 2025, INL/ANL-W WG meeting.

# EBR-II description

- ◆ Designed by Argonne National Laboratory as a scale-up from Experimental Breeder Reactor-I and operated from 1961 to 1994
- ◆ Liquid metal fast breeder reactor with passive safety features
- ◆ Unmoderated core with 67% enriched uranium (U)-235, sitting in a tank of liquid sodium primary coolant, and cooled by a closed-loop liquid sodium secondary circuit
- ◆ Maximum power level of 62.5 megawatts-thermal (MWth) and 20 megawatts-electric (MWe)
- ◆ Onsite reprocessing of spent fuel into new fuel pins
- ◆ EBR-II placed in “High” category because the only sodium-cooled fast reactor in the OTIB-0054 default library is the Fast Flux Test Facility (FFTF) at the Hanford site, which used mixed uranium and plutonium oxide fuel while EBR-II used only high-enriched metal alloy fuel

# BORAX-IV description

- ◆ BORAX series of reactor experiments tested the feasibility and safety and explored the operating parameters of direct steam production in a light-water reactor (boiling-water reactor)
- ◆ BORAX-IV operated from 1956 to 1958 at a maximum power of 20 MWth and 2.5 MWe and at 300 pounds per square inch primary water coolant pressure
- ◆ Tested U-233, U-235, and thorium oxide ceramic fuel plates; some of the experiments intentionally caused fuel failure
- ◆ BORAX-IV was placed in the “High” category because its fuel consisted of a mixture of uranium and thorium oxides, which is outside the range of fuels found in OTIB-0054, and because it operated for only short campaigns resulting in low fuel burnup

# OTIB-0054 reactor modeling overview

- ◆ The complex reactor physics modeling process in ORAUT-OTIB-0054 consists of cross-section and source term generation, decay time specifications, physical and operational reactor specifications, and dose calculations.
- ◆ OTIB-0054 source terms were generated using the TRITON and ORIGEN modules in the SCALE code system.
  - SCALE, a widely used comprehensive reactor modeling system developed by Oak Ridge National Laboratory for nuclear safety analysis and design, contains many modules, including TRITON and ORIGEN.
  - TRITON, a reactor physics module for transport, depletion, and sensitivity analyses, generated radionuclide concentrations as a function of burnup.
  - ORIGEN, a general-purpose point depletion and decay module, generated fission and activation product inventories for OTIB-0054's standard library of 4 reactors and 9 cases.

# OTIB-0054 standard reactor modeling library

<b>Reactor Type</b>	<b>Reactor Model</b>
High flux reactor	Advanced Test Reactor (ATR)
Sodium-cooled fast reactor	Fast Flux Test Facility (FFTF)
Plutonium production reactor	Hanford N-Reactor
Research reactor	Training, Research, Isotopes, General Atomics (TRIGA) Reactor, stainless steel cladding

# ORAUT-RPRT-0099 reactor modeling

- ◆ ORIGEN generated radioisotope inventories for the EBR-II and BORAX-IV reactors at 10 days, 40 days, 180 days, and 1 year to conceptually correspond to different stages in the fuel cycle.
- ◆ RPRT-0099 assessed OTIB-0054 applicability to the reactors by comparing doses calculated with two approaches:
  1. OTIB-0054 with its built-in source term and other data for its standard FFTF, ATR, and TRIGA reactors
  2. Source terms and other data generated specifically for EBR-II and BORAX-IV based on available operational and physical information
- ◆ Operational and exposure scenarios were the same, as were the assumed gross beta and gross gamma measurements (urine samples for 2-year and 10-year chronic exposures).

# ORAUT-RPRT-0099 dose comparisons

- ◆ RPRT-0099 compares doses calculated using the standard, generic OTIB-0054 library to those calculated using reactor-specific data by looking at ratios of the two methods for worst case 2- and 10-year chronic exposures to different organs:
  - Ratios greater than 1.000 imply that the generic ORAUT-OTIB-0054 approach is more claimant favorable.
  - Ratios less than 1.000 imply that the generic approach is less favorable.
- ◆ **Results:** All dose ratios are greater than 1.000 for EBR-II and BORAX-IV reactors, which indicates that the standard, generic OTIB-0054 approach is more claimant favorable than the reactor-specific approach, the degree ranging up to about a factor of 9.

# SC&A evaluation summary

- ◆ SC&A had reviewed OTIB-0054 as part of the procedures review process, and all findings have been resolved: OTIB-0054 uses claimant-favorable assumptions and produces claimant-favorable internal doses.
- ◆ However, experimental reactors EBR-II and BORAX-IV have physical and operational characteristics that place them outside the space in which OTIB-0054, with its standard, generic cases, was intended to operate.
  - EBR-II was liquid-metal cooled and used highly enriched uranium metal fuel.
  - BORAX-IV fuel consisted of uranium and plutonium oxides, and the reactor was operated for short campaigns with low fuel burnup.
- ◆ SC&A reviewed RPRT-0099 and relevant data.
  - Although it did not conduct its own independent SCALE or OTIB-0054 modeling, SC&A is confident that the underlying analysis is correct.

# SC&A conclusions and recommendations

- ◆ SC&A concurs with NIOSH's assertion that, at least for these two reactors, the standard, generic OTIB-0054 approach can be used to determine claimant-favorable internal doses when only gross gamma or gross beta data are available.
- ◆ Under certain circumstances, the standard, generic OTIB-0054 approach may overestimate the reactor-specific organ doses by up to a factor of 9 (details are in SC&A's review of RPRT-0099).
- ◆ SC&A recommends that NIOSH follow up its analysis with a discussion of why and under what conditions significant overestimation might happen.

# Future reactor analyses

- ◆ EBR-II and BORAX-IV were part of a group of six reactors that operated during the SEC evaluation periods for INL and ANL-W and that SC&A, NIOSH, and the WG classified as high-priority reactors needing further evaluation.
- ◆ NIOSH stated in RPRT-0099 that it is currently conducting corresponding analyses for the other high-priority reactors on the INL/ANL-W site and will report on them separately.



# Questions?